Contribution of Chromospheric Features to UV Irradiance Variability from Spatially Resolved Call K Spectroheliograms

1. A New Method of Analysis and Preliminary Results

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CONTRIIWTION OF CIIROMOSPIIERIC FEATURES TO UV IRRADIANCE VARIABILITY FROM SPATIALLY RESOLVED CAII K SPECTROIIEL1OGRAMS

I. *A New Method of Analysis and Preliminary Results*

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Abstract. A detailed analysis of CaII K spectroheliograms observed at the National Solar Observatory at Sacramento Peak started at the Jet Propulsion I~bm-story, California Institute of Technology as a collaborative effort with NSO/Sac Peak in 1994. We have digitized spectroheliograms for 1980 (maximum of SC21), 1985 (minimum of SC21), 1987 (beginning of the ascending phase of SC22), 1988 and 1989 (ascending phase and maximum of SC22), and 1992 (declining phase of SC22). A new method for analyzing the K spectroheliograms has been developed and applied to the Cal I K images for the time interval of 1992. Using the so-called "histogram method" in an IDL programming language routine, we have separated the plages, magnetic network and intranetwork elements. 'l'he intensity and area of the above features and the full disk intensity (spatial K index) have been measured. The full width at half maximum (FWIIM) derived from the histograms has been introduced as a new index for describing the chromospheric activity in K-line. The spatial K index has been compared to the spectral K index derived from the line profiles by S. Keil at the NSO/Sac Peak and to the CaII spectral irradiance measured by G. Chapman at the San Fernando Observatory at Northridge. Both the spatial K index and the intensity of plages, the magnetic network and intranetwork elements have been

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compared to the UV irradiance measured in the MgII h & k lines by the UARS and NOAA9 satellites. It has been found that the spatial K index and intensity of plages, network elements and intranetwork elements are highly correlated with the MgII h & k c/w ratio. Our study shows that besides the plages, a significant portion of the variations observed in UV irradiance is related to the changing emission of the network and intranetwork elements and in addition to plages and network, the intranetwork elements may also play a significant role in their contribution to the variation in UV irradiance. It has been shown that the intensity of the intranetwork elements is not constant as assumed in the current irradiance models. In contrast, it is changing in a fashion similar to the plages and the magnetic network. Our results show an anticorrelation between the intensity and area of the network elements and this means that during solar minimum the network is fainter but covers a larger area than during solar maximum, These results suggest that the variation in both the intensity and the area of the various spatial features have to be taken into account in irradiance models.

1. introduction

Since the radiative output of the Sun is one of the main driving forces of the terrestrial atmosphere and climate system, study of the changes in the solar energy flux has recently become of high interest. Although the long-term change. in total solar irradiance (the solar energy flux integrated over the entire spectrum) can be considered as one of the major natural forces of the Earth's climate system, study of UV irradiance variability is an equally important issue. Although the solar radiation below 300 nm represents only 1 % of the total solar energy flux, the UV irradiance plays a significant role in heating the upper atmosphere of the Earth and establishing its chemical composition through photodissociation and photoionization processes. Because of this, changes in UV irradiance influence the concentration of ozone and other important stratospheric constituents in the Earth's atmosphere and may play an important role in the process of global warming (e.g. Hood *et al.*, 1993). Therefore, considerable research efforts have been put forward to observe and analyze the changes in solar UV irradiance. For more than a decade, solar irradiance (both bolometric and at various wavelengths) have been monitored from several satellites. These space irradiance observations have shown that the solar energy flux changes over the solar cycle, being higher during maximum activity conditions, and short-term changes (from days to months) are superposed on the long-term variation (e.g. Hudson, 1988; Frohlich, 1994). The long-term irradiance variations are attributed to the changing emission of bright magnetic elements, including plages and the magnetic network (Foukal and Lean, 1988). The short-term irradiance variations are directly associated with active. regions as they evolve and move across the solar disk (Lean, 1987). It has been shown that besides the plages, the plage remnants and the magnetic network also contribute to the short-term changes in solar UV irradiance (Pap *et al.*, 1991; Pap, 1992). Although considerable information exists on solar irradiance variability, its physical origin is not yet understood. There is a significant residual variability in both solar total and UV irradiance at periods of 300, 27, 13.5, and 9 days that is not explained by the effect of plages and the magnetic network (Pap and Frohlich, 1992, Pap, 1992). However, the current irradiance models are based on full disk surrogates, such as the 10.7 cm radio flux (Barth *et al.*, 1990), the full disk CaII K index (Livingston, 1994) and the HeI line equivalent width at 1083 nm (Foukal and Lean, 1988, Pap, 1992), therefore they cannot provide adequate information on the physical causes of the observed irradiance changes. In order to identify and understand the underlying physical mechanisms of solar irradiance variability, detailed analysis of spatially resolved data is required.

Photometric observations of the Sun have been performed at several observatories which make it possible to measure the area, intensity, flux excess and deficit of solar magnetic features causing variations in solar irradiance. The Call H & K resonance lines are widely used to study the solar chromospheric structures. These lines are very sensitive to the variations in temperature and the magnetic field strength, therefore they are excellent indicators of the chromospheric structural changes related to solar magnetic activity. Analyses of two-dimensional solar images (spectroheliograms) in the Call H & K lines demonstrate that the main features responsible for chromospheric emission are (1) the so-called background and the intranetwork regions; (2) the network elements, which are co-spatial with the boundaries of supergranular cells in the underlying photospheric levels; and (3) the bright plages. It has been shown that the chromospheric emission from the CaK plages is modulated by solar activity on both the active regions time scale and over the solar cycle (e.g. Bossy, 1983; Lean, 1987). However, changes in the network and intranetwork elements related to solar activity are less understood, especially because of the lack of systematic and quantitative. measurements of these chromospheric features. Therefore, detailed analysis of the chromospheric fine structure is crucial for understanding the underlying physical mechanism of solar irradiance variability. In addition, another major scientific goal is to determine the exact amount of the contribution of the above listed structures to the changes in UV irradiance (Sofia *et al.,* 1982; Lean *et al.,* 1982; Pap, 1992; Kariyappa and Sivaraman, 1994) and incorporate the result into the irradiance models. improvement of the current models is extremely important in order to reconstruct the changes in UV irradiance and to predict the solar-induced variations in the Earth's atmosphere. The main purpose of this paper is to separate and derive the intensity and area of various chromospheric features, such as plages, the magnetic network and intranetwork elements from the CaII K spectroheliograms taken at the National Solar Observatory at Sacramento Peak and compare the changes of these spatially resolved features with solar UV irradiance variability. Results for the time interval of 1992 are presented in this paper.

2. Observations and Reduction of the CaII K Spectroheliograms

The CaII K spectroheliograms, used in this study, have been observed at the National Solar Observatory at Sacramento Peak (NSO/Sac Peak) with the K-spectroheliograph at the J. W. Evans facility. The K-spectroheliograph is an instrument with a grating of 308.57 lines/mm and ruled area of 100 mm x 203 mm and with a dispersion of 1.167 mm/Å at 3934Å. The spectroheliograms employ a 10 cm image with a spectral window of 0.5Å centered at K232. The image scale is about 0.050 mm/arcsec. We have selected and digitized daily spectroheliograms for a 6-year long time interval, when each year represents different phase of the solar cycle, , namely 1980 (maximum of SC21), 1985 (minimum of SC21), 1987 (the beginning of the ascending phase of SC22), 1988 and 1989 (ascending phase and maximum of SC22), and 1992 (descending phase of SC22). The main criteria for selecting spectroheliograms for this analysis are the following: (1) the seeing is good to excellent; (2) the negatives are well exposed; and (3) good step wedge calibration is available on each image. The full disk K spectroheliograms have been digitized with the high speed microdensitometer of the NSO/Sac Peak. The sampling aperture used corresponds to 1 arcsec resolution on the Sun, yielding high resolution images of 1980 x 2230 pixels in each image. One of the K images is shown in Figure 1 for July 24, 1992. The step wedge calibration on the individual spectroheliograms has also been digitized to maintain a homogeneous set of images. The digitized pixel values have been converted into relative intensities using a 3rd degree polynomial fit calibration curve, following the standard photographic density-to-intensity reduction procedure. We have corrected the full disk images for the background emulsion noise by taking the mean value of the emulsion at the corners of image, well beyond the solar limb. The unwanted areas surrounding and beyond the limb have been masked and the images have been corrected for the limb darkening by fitting a 3rd degree polynomial to the surface of the solar image.

Images for the time interval of 1992 have been analyzed and the first results of this analysis are presented in this paper. The following parameters have been derived from the images of 1992:

(i) Histogram plots for the full disk:

- (a) Full Width at Half Maximum (FWHM)
- (b) Peak pixel numbers
- (c) Peak intensity

(ii) Disk center intensity in a quiet region and full-disk Cal K index

(iii) Intensity of plages, network, and intranetwork elements

(iv) Number of pixels occupied by plages, network, and intranetwork elements. Further data handling will also be described below, together with the results.

3. Results and Discussions

3.1. Histogram Method

To analyze the full disk Call K spectroheliograms and to separate various magnetic features, the so-called "histogram method" has been used. After applying the corrections described in the previous section, we derived the number of pixels corresponding to the measured pixel intensity values, The histograms, which represent the distribution of the number of pixels versus the corresponding intensity values, have been plotted fot each selected image, Two particular histograms are presented in Figure 2. The solid curve in Figure 2 shows the histogram of a CaII K image taken on April 8, 1992 during low activity conditions. The dotted curve represents a histogram for April 15, 1992 when more plages were present on the Sun. In general, the pixel intensity values for intranetwork elements fall in the toe portion, for network elements in the peak portion and for plages in the tail portion of the histogram plot. However, as can be seen from Figure 2, the shape of the histograms for lower and higher activity conditions is quite different, Our study shows that during low activity conditions, when only a few plages are on the Sun, the width of the histograms is very narrow. In addition, the most probable pixel number is at low intensity values, indicating that most of the chromospheric radiation is emitted from the network and intranetwork elements. In contrast, when the Sun is more active, the histogram is shifted towards higher intensities and the maximum peak pixel number has a significantly lower value. It is interesting to note that during higher solar activity conditions the histograms are systematically wider than during lower activity. Based on this result, we have introduced the so-called "Full Width at Half Maximum" (FWHM) which has a direct correlation with the strength of the solar activity. As we shall see in the discussion to follow, the FWHM can be used as an important parameter in studying the K line variability associated with solar activity.

.3.2. *Full Disk CaII K Index*

As a first step, before separating the various chromospheric features, we have derived the full-disk CaII K index (thereafter called as "spatial K index"). The spatial K index, which represents the total integrated intensity for the full disk from all the chromospheric features, has been normalized to the disk center intensity values in a quiet region from the K spectroheliograms. In order to test our measurements, we compared the spatial K index to the so-called "spectral K index" which has been derived from the K-1ine profiles observed at the NSO/Sac Peak. The Sac Peak spectral K index is defined as the total flux in a 1Å bandpass centered on the K emission line core (Keil and Worden, 1984). An additional source of K observations has been used in our study. The full disk Cal I K spectral irradiance values have also been produced cm a daily basis by G. Chapman at tile San Fernando Observatory (SFO), California State University at Northridge to study the variations in solar irradiance due to the excess flux of bright magnetic elements (Chapman *et al.*, 1992). 'l'he excess flux is estimated at SFO from the violet 3934Å K line with a 10Å bandpass filter. The facular pixels are determined from the SFO K-line images with contrast enhanced above the continuum levels. The bright pixels identified as faculae are added and weighted by the limb darkening to get the final values of the Cal I K spectral irradiance (Chapman *et al.*, 1992).

The full disk K indices have also been compared to the UV irradiance measured by the SOLSTICE instrument on the Upper Atmosphere Research Satellite (UARS) and the NOAA9/SBUV2 instrument. It has been shown that the ratio of the irradiance in the core of the Mg 11280 nm line to the irradiance at neighboring continuum wavelengths can be used as an index (Mg 11 h & k core-to-wing ratio) of solar variation (Heath and Schlesinger, 1986). The Mg 11 core-to-wing ratios have been derived from both the UARS and NOAA9 measurements (Rottman *et al.*, 1994; Donnelly *et al.*, 1994). Since the formation of the Cal I and MgII lines is very similar and they both originate from the same chromospheric layers, we have used these ratios derived from the NOAA9/SBUV2 and UARS/SOLSTICE UV observations to compare with the various parameters of our K-images.

Figure 3 shows the time series of the spatial K index (a), the Full Width at Half Maximum (FWHM) (b), the NSO/Sac Peak spectral K index (c), and the SFO CaII K irradiance (d). The UV irradiance data measured by the UARS/SOLSTICE and NOAA9/SBUV2 instruments are plotted in Figs. 3e and 3f, respectively. As can be seen, the variations of the spatial K index and the FWHM are very similar (r = 0.95), indicating that FWHM is a good index for (inscribing the variability of the K line. It should be noted that one of the largest problems in analyzing photographic images is the selection of the quiet-Sun regions which are used to normalize the final values of the full disk indices. It is extremely difficult to separate the quiet-Sun component from a chromospheric network component to account for the total amount of radiation from chromospheric layers. Thus, there is the possibility of slow secular changes globally in the Sun (Pap and White, 1995) which increases the uncertainty of the full disk K indices. In contrast, the estimation of FWHM is based on the peak intensity values and the width of the histogram, therefore it is less affected by the correct selection of the quiet-Sun regions. Although further investigations are required on this topic, the introduction of FWHM provides a promising new method to estimate the full disk K flux derived from photographic photometry.

As can be seen from Figure 3, both the spatial K index and FWHM vary in parallel with the NSO/Sac Peak spectral K index and the SFO CaII irradiance as well as the UV irradiance. These time series show that the activity level was still high at the beginning of 1992. However, there was a fast drop in both the full disk CaK intensities and UV irradiance, similar to other activity indices between February and June of 1992 (White et al., 1994). This significant drop in solar activity arose from the disappearing magnetic activity on the southern solar hemisphere (Harvey, 1994). It is interesting to note that after June 1992, both the Cal] K and UV data show a relatively flat variation dominated by the 27-day solar rotational variability. The corresponding scatter plot diagrams between the spatial K index and the NSO/Sac Peak and SFO full disk K indices as well as the UV irradiances are presented in Figures 4a to 4d. The same is plotted for the FW1 lM in Figures 4e to 4h. The corresponding correlation coefficients are given on each plot and also summarized in Table 1.

As can be seen from Table 1, the correlation coefficient between the NSO spectral K index and the SFO CaK index is 0.85, in spite of the fact that the spatial K index has been derived from photographic photometry. On the other hand, the correlation between the spatial K index (and the FWHM) and the Mg 11 core-to-wing ratios are significantly lower compared to the correlation coefficients of the other two K indices. However, we note that there are more missing data in the spatial K index than in the two other K indices. We anticipate that the relation still may improve after including the remaining 5 years of data because of the large dynamical range in solar activity.

3.3. Extraction of spatially resolved features

The intensity and the number of pixels for plages, network, and intranetwork elements have been derived from the digitized spectroheliograms. In order to separate these features, each histogram has been plotted and divided into three parts depending upon the pixel intensity values. However, as our results show, the distribution of the pixel intensity is strongly associated with the actual level of solar activity. Therefore, the various solar features cannot be separated from a single analysis of the histograms. Parallel study of the. morphology of various features is required to properly separate them and to estimate their area and intensity values. For this purpose, we first guessed at the intensity levels that might bound the network pixels in a histogram, and then examined images in which the pixels with greater or lesser intensities than those bounds were masked. The bounding intensities were then adjusted until the masked image accurately mapped the network regions. Similar processes were used for the plages and intranetwork features. The intensity and the number of pixels for plages, network and intranetwork regions have been derived from these images using their corresponding histogram plots.

The left side panel of Figure 5 shows the time series of the intensity of' plage, network, and intranetwork elements. As expected from previous analyses, the intensities of plages and the network decrease from maximum activity conditions to solar minimum (e.g. Foukal and Lean, 1988), in a similar fashion with the full disk Ca K intensity values and the Mg core-to-wing ratios. It is interesting to note that the intranetwork elements also show a similar variation during 1992 like the plages and the network. '1 'he areas (total pixel numbers) of plages, network and intranetwork elements are plotted on the right side pane] of Figure 5. As can be seen, the plage area shows a very similar variation over 1992 with that of the plage intensity, indicating that during high solar activity conditions the plages cover larger area (Lean, 1987). However, our results indicate an anticorrelation between the intensity and area of network for the time interval of 1992 (r=-0.35 and also see Tables II & III).

'] 'he mean intensity and area values of the various features are summarized in Table 11 for the whole period, for the maximum activity (January to February), and minimum activity (March to December) during 1992. The differences between the intensities and areas during high and low solar activity conditions are also listed for the investigated features. As we can see in Table 11 (and Figure *2)*, the intensity decreased from high to low activity conditions in the case of each feature. However, it is interesting to note that the decrease of the intensity of the network and intranetwork elements is much less than that of the plages. In addition, while the area of plages decreases from high to low activity conditions, both the network and intranetwork area is increased during low solar activity. We note that a similar conclusion was reached by studying a large sample of the Kodaikonal CaII K spectroheliograms covering the period from 1957 to 1983 (Kariyappa and Sivaraman, 1994).

The relation between the plages, network, intranetwork elements and the Mg II core-to-wing ratios has been studied as well. The corresponding scatter plot diagrams between the intensity and area of the various features and the NOAA9/SBUV2 and UARS/SOLSTICE Mg II core-to-wing ratios are presented in Figures 6 and 7, respectively. The correlation coefficients are printed on the appropriate plots and also summarized in Table III.

As can be seen, neither the variation of the intensity nor the. area of the listed features contributes significantly to the changes in UV irradiance. Statistically, the intensity of the plages accounts for about 18% of the UV variability during 1992, while the network and intranetwork contribution account for about 14%, respectively. The correlation between the variation of the Mg II core-to-wing ratio and the network area is negative. If we compare the plots of time series of MgII core-to-wing rates (Figures 3e and 3f) with the network area (Figure *7), we* can see that the network area increases with the decrease of UV irradiance in MgII core-to-wing ratio. This result demonstrates that both the intensity and area values of the various spatial structures have to be taken into account in the irradiance models. Although the network and intranetwork elements are much fainter than the plages, they cover a large fraction of the solar disk and therefore they may contribute significantly to the changes in UV (and total) irradiance, especially during solar minimum. These results may explain the discrepancy between the current UV models and measurements at the time of solar minimum (Barth *et* al., 1989; Pap *et* al., 1991).

4. conclusions

A detailed analysis of the CaII K spectroheliograms, taken at the National Solar Observatory at Sacramento Peak, has been carried out for the time interval of 1992. We have derived the full disk Call K index, called Spatial K index, and also measured the intensity and the area of the plages, network, and intranetwork + background regions from the K-spectroheliograms using the histogram method. The spatial K index correlates well with other full disk K indices derived from the K line profiles (Keil and Worden, 1984) and measured at the San Fernando Observatory (Chapman *et* al., 1992). The full width at half maximum (FWHM) derived from the histograms has been introduced as a new index for measuring the chromospheric activity in K-1ine. Since the spatial K index is calibrated with the quiet-sun intensity, its value may be influnced by the small fluctuations in the quiet-sun values which still may be of solar origin, In contrast, the value of FWHM dots not depend on the choosen quiet-sun regions, therefore, it may provide a more appropriate index for solar variability observed in the Call K-line.

It is shown that the spatial K index, FWHM and the intensity of plages, network, and intranetwork elements vary in a fashion similar to solar UV irradiance represented by the MgII core-towing ratio calculated from the irradiance observations of the NOAA9/SBUV2 and UARS/SOLSTICE instruments. All these indices show the fast decline between March and June, 1992 related to the disappearing magnetic activity of the south solar hemisphere (Harvey, 1994). While the fraction of the solar surface covered by plages is significantly less during solar minimum than during solar maximum (Foukal and Lean, 1988), our results show that the area of the network increases during minimum activity conditions in 1992 (between March and December). The anticorrelation found between the intensity and area of the network indicates that during solar minimum the network is fainter but it covers a larger area and therefore it may give a significant contribution to irradiance changes. These results, based on the analysis of spatially resolved data, confirm previous results derived from full disk indices, e.g. the full disk equivalent width of the HeI-line at 1083nm (Foukal and Lean, 1988; Pap, 1992). Note that Kariyappa and Sivaraman (1994) reached a similar concision by studying a large sample of the Kodaikanal CaII K spectroheliograms covering the time interval of 1957 to 1983.

Our results demonstrate that both the area and intensity of various magnetic activity features must be taken into account in the irradiance models. Further studies are required to estimate the contribution of intranetwork elements to solar irradiance variations. A detailed study of CaII H-line profiles over a quiet region at the center of the solar disk by Kariyappa *et al.*, *(1* 994) and Kariyappa (1 994) aiso shows that the inner network bright points and the network elements arc the sites where substantial energy is dissipated to heat the chromosphere and hence may also contribute to the changes in solar UV irradiance. Further analysis of the Sac Peak spectroheliograms is already in progress to validate the above results and to study the contribution of various magnetic features as a function of solar cycle.

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TABI .E 1

Correlation coefficient between the full disk Call K indices, FWHM and the MgII core-to-wing ratios

	Spatial K Index	FWH M	NSO	SFO
	Linear correlation coefficients			
FWHM	0.95	1.00	0.78	0.80
NSO Spectral K	0.79	0.78	1.00	0.85
SFO CaK	0.80	0.80	0.85	1.00
NOAA9/Mg c/w	0.75	0.65	0.92	0.88
UARS/Mg c/w	0.71	0.72	0.91	0.88

TABLE 11

The mean intensity and area of plages, network, and intranetwork elements are listed for the entire 1992 time interval, for maximum activity between January and February and for minimum activity between March and December. The differences between the intensities and areas from high to low activity conditions are also presented

Mean Intensity	1992	Jan. -Feb. 1992 High Activity	March-Dec. 1992 Low Activity	Difference High - Low Activity
Plage	72.24	98.2	68.03	30.2
Net work	46.14	57.06	44.41	12.6
Intranetwork	26.54	38.45	24.61	13.8
Mean Area (Pixel Number)				
Plage	14646	17473	14188	3285
Net work	85397	79888	86290	-6402
Intranetwork	94070	93781	94117	-336

TABLE III

The linear correlation coefficients between the intensity and area of plages, network, and intranetwork elements and MgII core-to-wing ratios

	NOAA9/SBUV2/MgII C/W	UARS/SOLSTICE/MgII C/W
	Correlation coefficients	
plage intensity	0.42	*0.42*
network intensity	0.37	0.36
intranetwork intensity	0.37	0,36
plage area	0.39	0.39
network area	-0.37	-0.38
intranetwork area	0.03	0.03

Figure Captions

Fig. 1. A sample of Cal I K-Spectroheliogram observed cm July 24, 1992 at National Solar Observatory/Sacramento Peak from our collection.

Fig. 2. Histogram plots for the full disk Call K images of (a) April 8,1992, when there are less plages present on the solar disk and (b) April 15,1992, when there arc more plages on the solar disk. Notice that the full width at half maximum (FWHM) of the histogram plot is larger for (b) and it is very good indicator of the solar variability in K line.

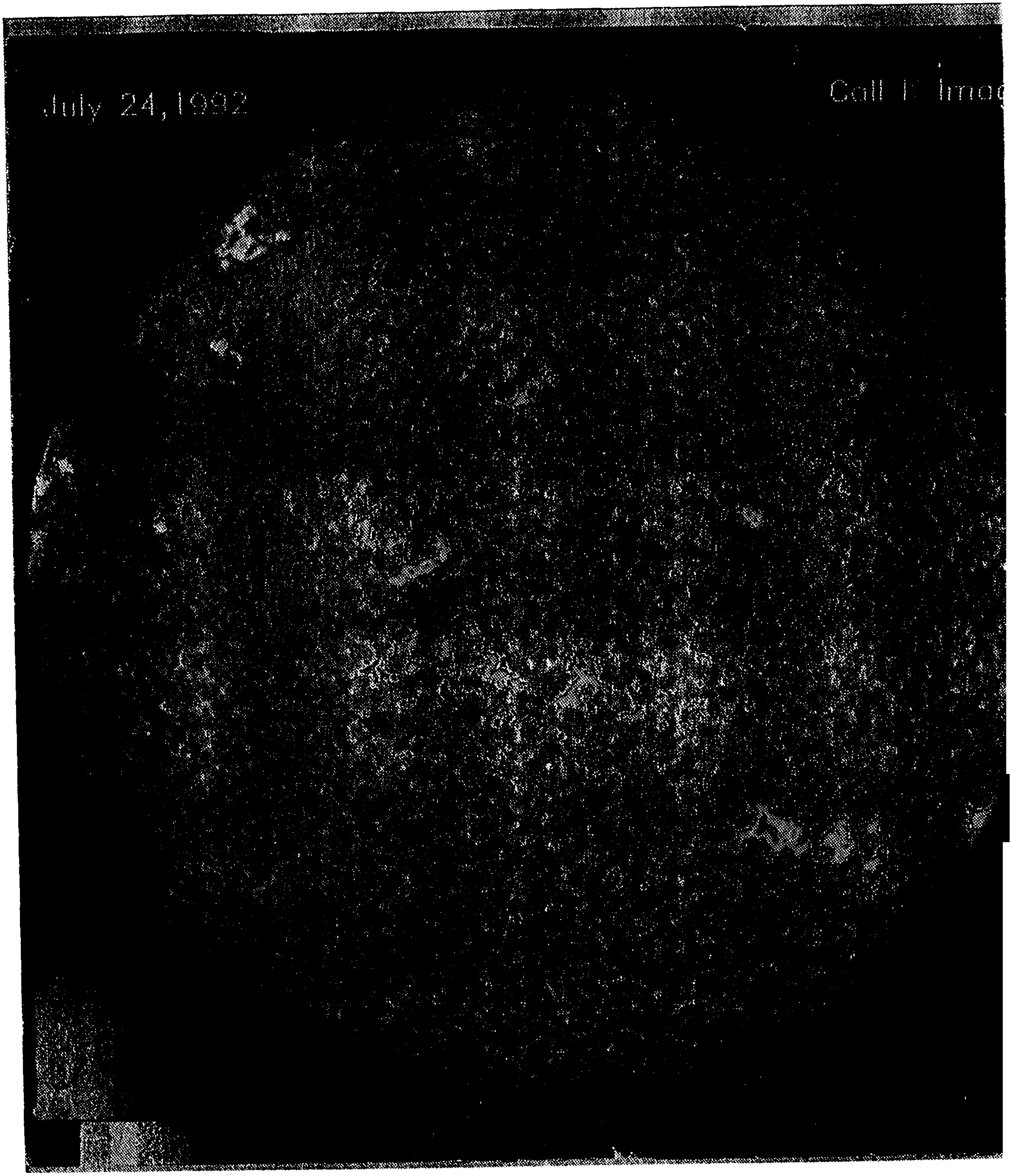
Fig. 3. Time series of (a) spatial K index, (b) full width at half maximum (FWHM), (c) NSO/Sac Peak spectral K index, (d) SFO Call irradiance, (e) UARS/SOLSTICE MgII c/w ratio, and (f) NOAA9/SBUV2 MgII c/w ratio.

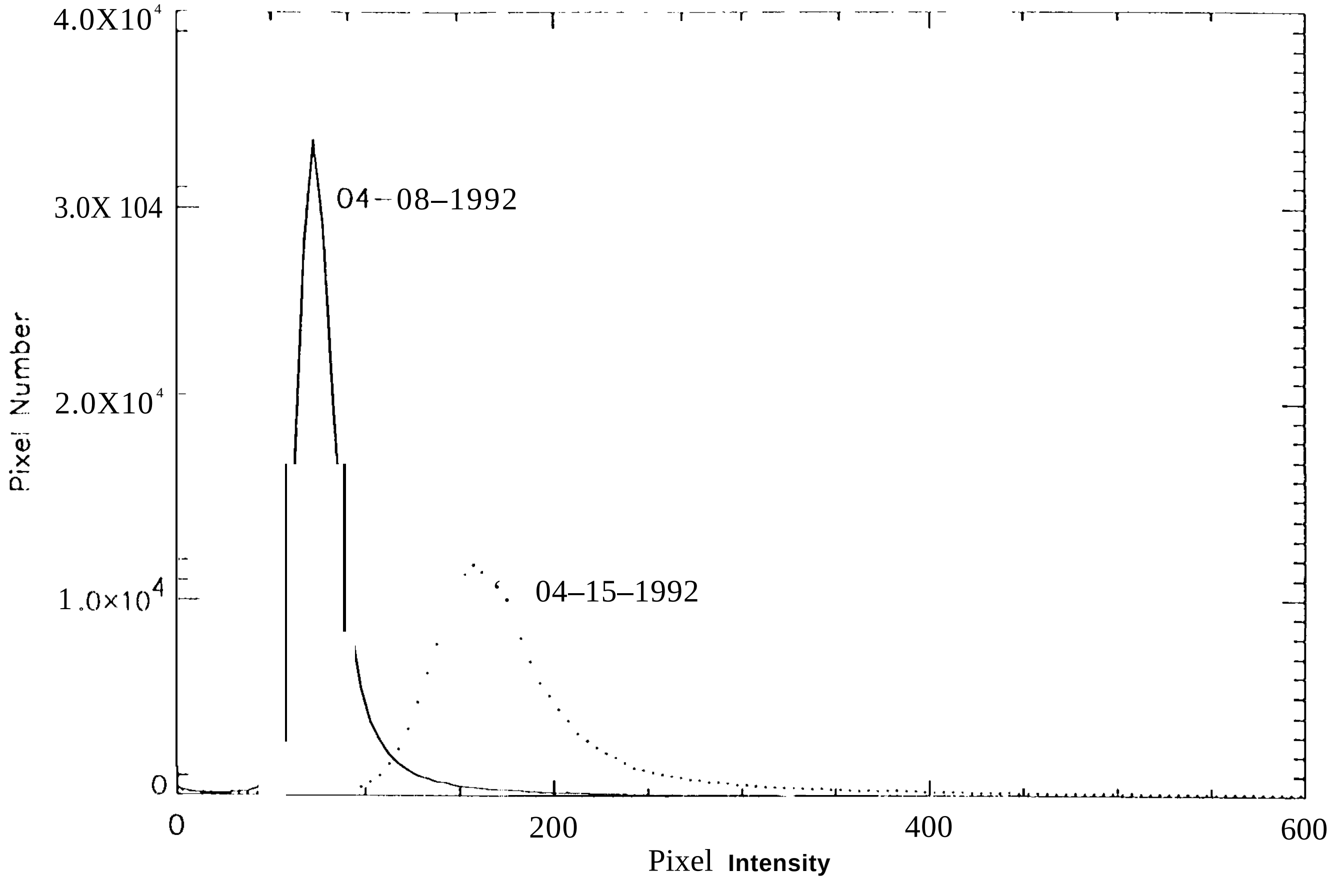
Fig. 4. Scatter diagrams of spatial K index versus (a) NSO/Sac Peak spectral K index, (b) SFO CaII irradiance, (c) UARS/SOLSTICE MgII c/w ratio , (d) NOAA9/SBUV2 MgII c/w ratio, and full width at half maximum (FWHM) versus (e) NSO/Sac Peak spectral K index, (f) SFO CaII irradiance, (g) UARS/SOLSTICE MgII c/w ratio, (h) NOAA9/SBUV2 MgII c/w ratio.

Fig. 5. Time series of intensity of plages, network elements and intranetwork elements (right side panel) and similarly for the time series of areas are plotted in left side panel.

Fig. 6. Scatter diagrams of NOAA9/SBUV2 MgII c/w ratio versus the intensity of (a) plage, (b) network, and (c) intranetwork elements, and UARS/SOLSTICE MgII c/w ratio versus the intensity of (d) plage, (e) network, and (f) intranetwork elements.

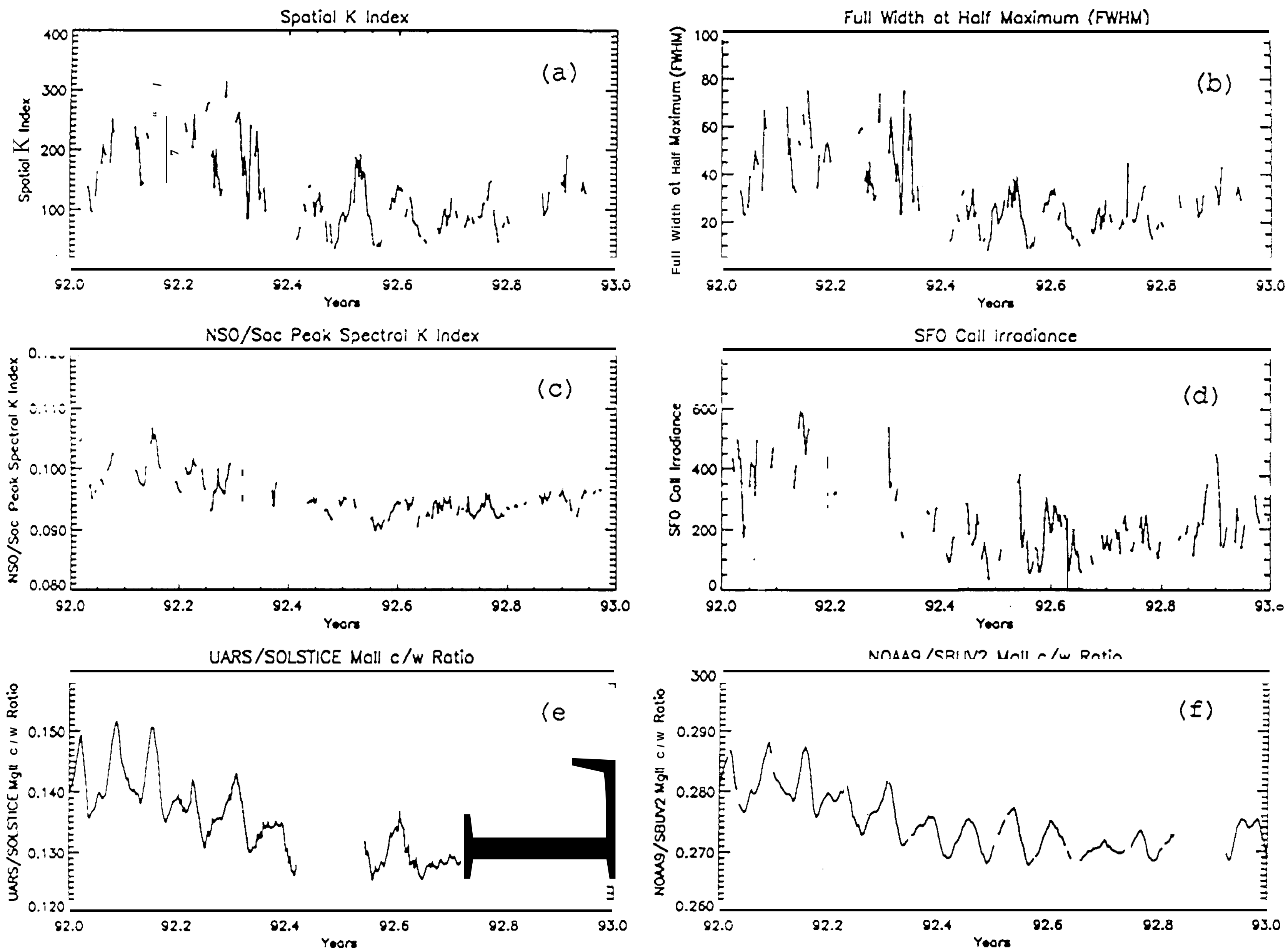
Fig. 7. Scatter diagrams of NOAA9/SBUV2 MgII c/w ratio versus area of (a) plage, (b) network, and (c) intranetwork elements, and UARS/SOLSTICE Mgl 1 c/w ratio versus area of (d) plage, (e) network, and (f) intranetwork elements.


July 24,1992
Call F



4.0X10⁴
3.0X 104
2.0X10⁴
1.0x10⁴
0
Pixel Number
04–08–1992
04–15–1992
0
200
400
600
Pixel Intensity

Fig. 2



Spatial K Index
(a)
Full Width at Half Maximum (FWHM)
(b)
NSO/Sac Peak Spectral K Index
(c)
SFO Call irradiance
(d)
UARS/SOLSTICE MgII c/w Ratio
(e
(f)
Years

fig. 3

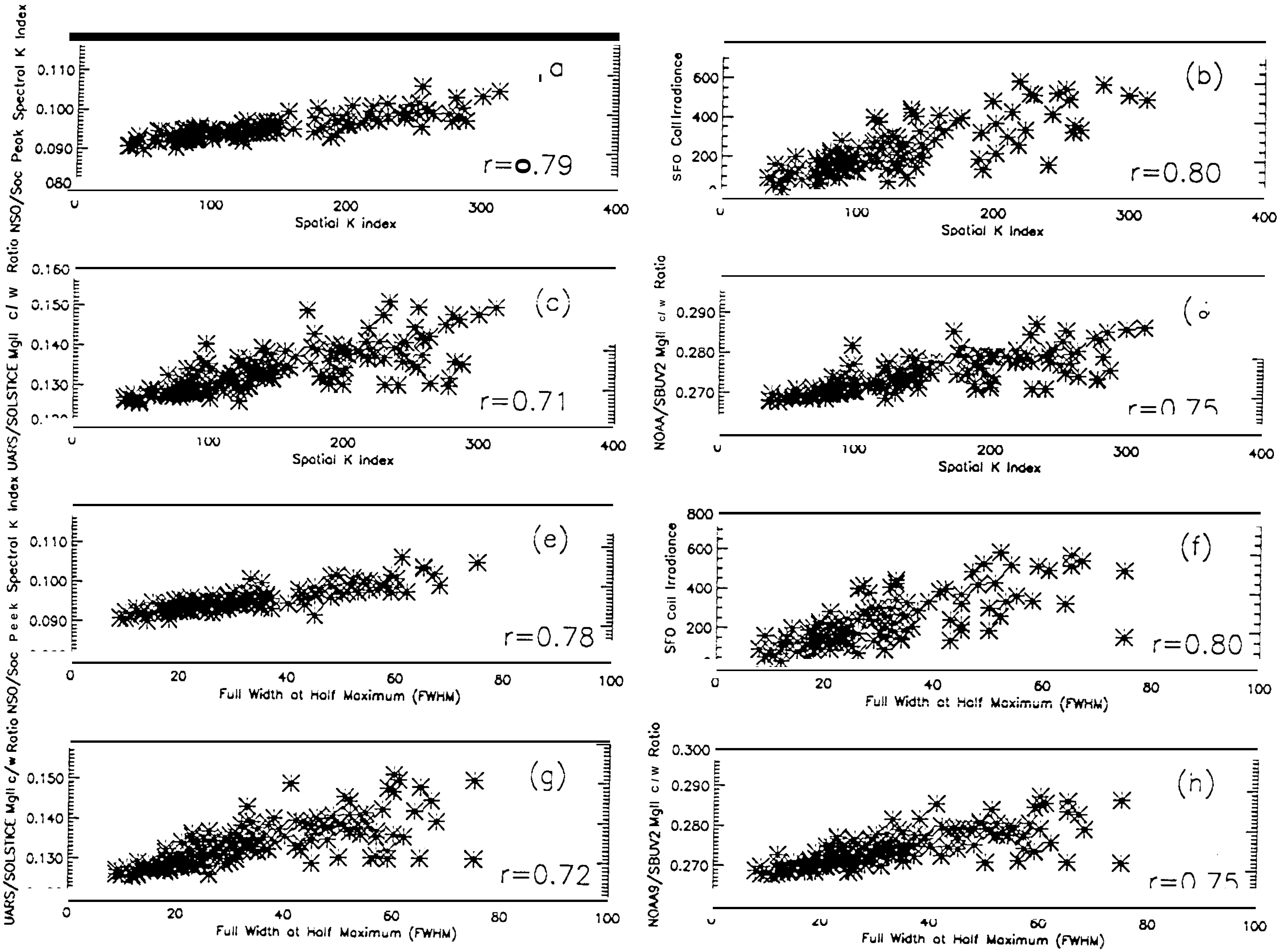
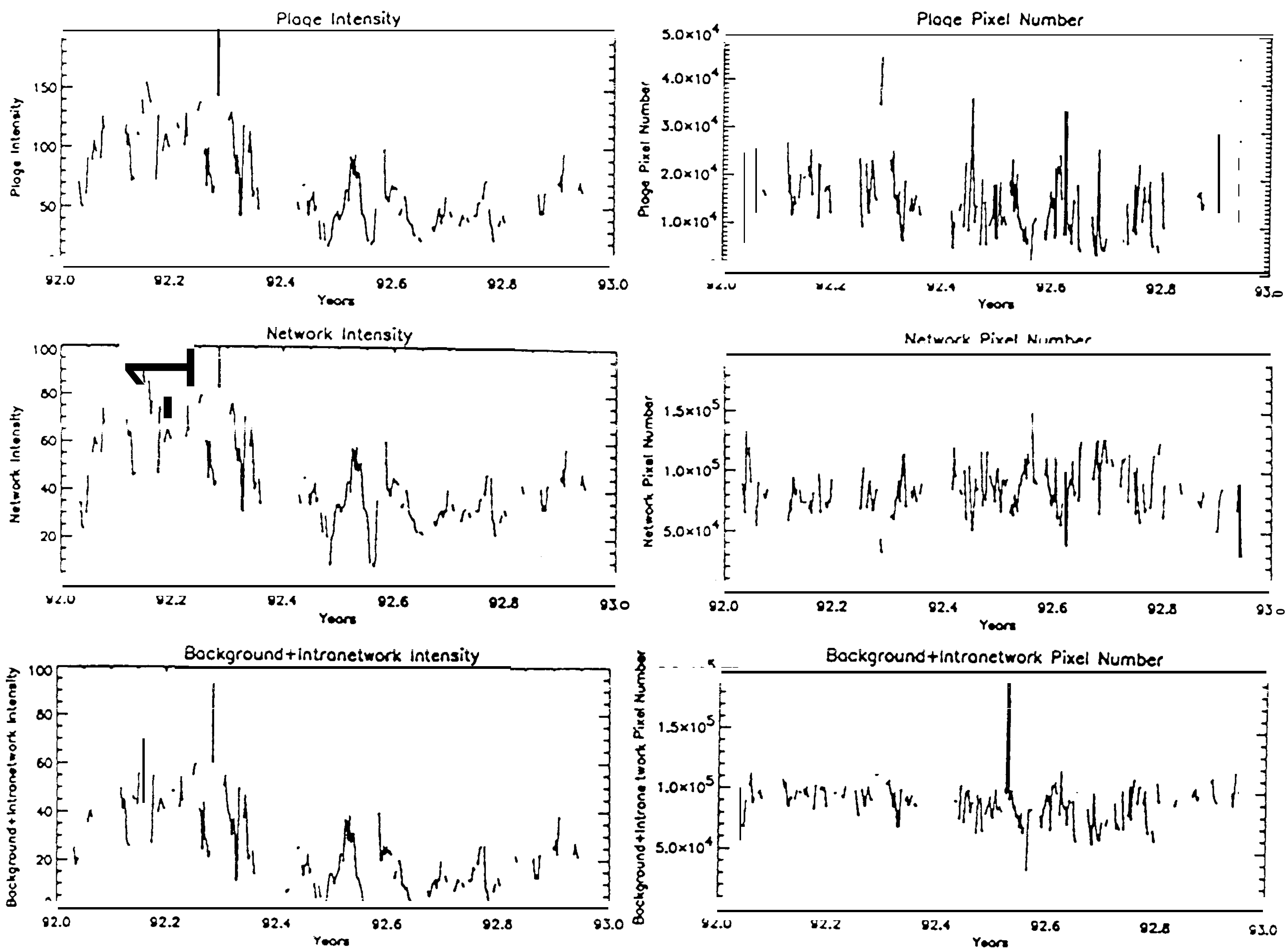

NSO/Sac Peak Spectral K Index
Spatial K index
r=0.79
a
SFO Call Irradiance
Spatial K Index
r=0.80
(b)
UARS/SOLSTICE MgII c/w Ratio
Spatial K index
r=0.71
(c)
NOAA/SBUV2 MgII c/w Ratio
Spatial K Index
r=0.75
NSO/Sac Peek Spectral K Index
Full Width at Half Maximum (FWHM)
r=0.78
(e)
SFO Coil Irradiance
Full Width at Half Maximum (FWHM)
r=0.80
(f)
UARS/SOLSTICE MgII c/w Ratio
Full Width at Half Maximum (FWHM)
r=0.72
(g)
NOAA9/SBUV2 MgII c/w Ratio
Full Width at Half Maximum (FWHM)
r=0.75
(h)

Fig. 4



Plage Intensity
Plage Pixel Number
Network Intensity
Network Pixel Number
Background+Intranetwork Intensity
Background+Intranetwork Pixel Number
Years

Fig. 5

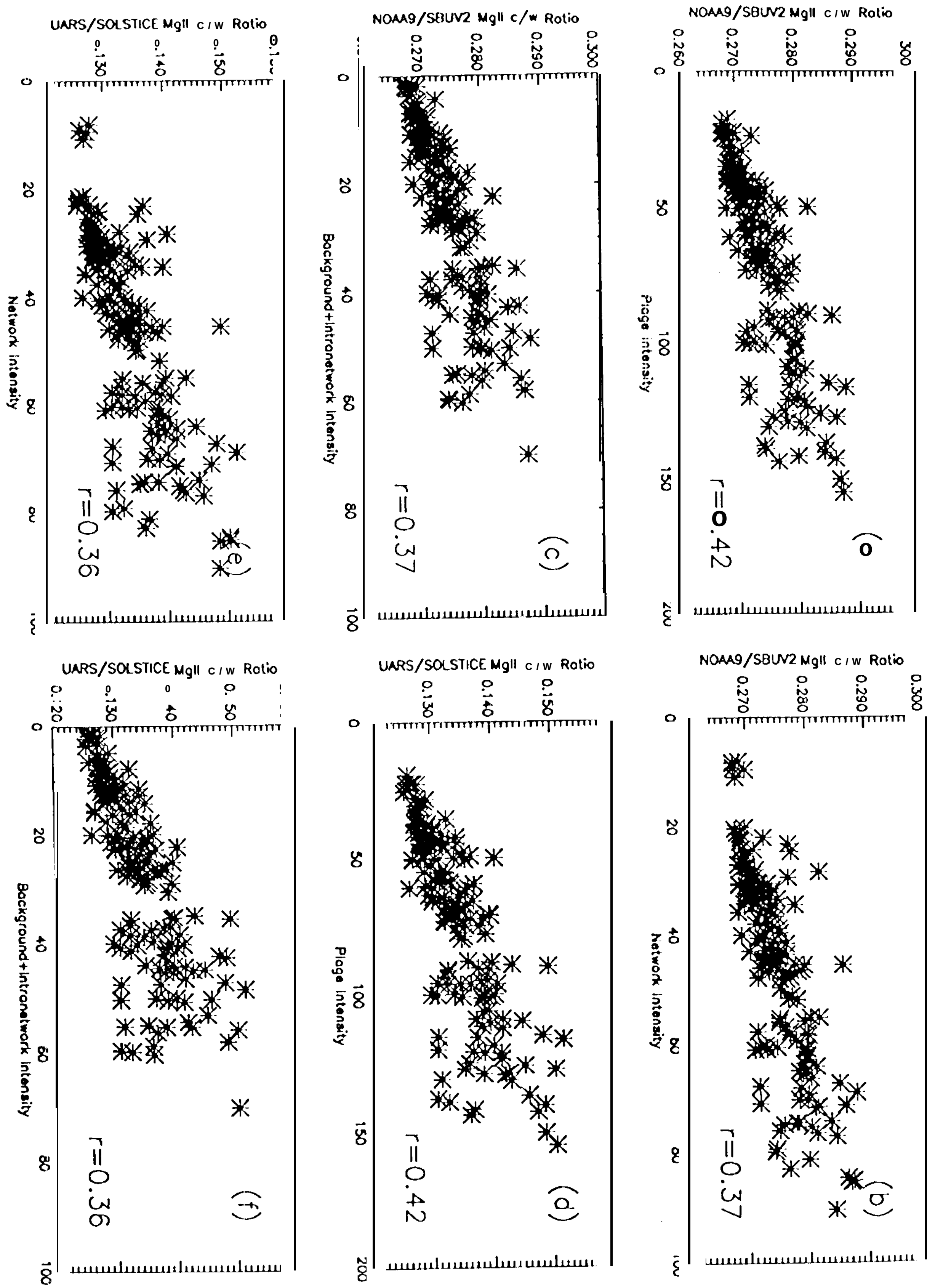

NOAA9/SBUV2 MgII c/w Ratio
Plage intensity
(a)
r=0.42
NOAA9/SBUV2 MgII c/w Ratio
Network intensity
(b)
r=0.37
NOAA9/SBUV2 MgII c/w Ratio
Background+intranetwork intensity
(c)
r=0.37
UARS/SOLSTICE MgII c/w Ratio
Plage intensity
(d)
r=0.42
UARS/SOLSTICE MgII c/w Ratio
Network intensity
(e)
r=0.36
UARS/SOLSTICE MgII c/w Ratio
Background+intranetwork intensity
(f)
r=0.36

Fig. 6

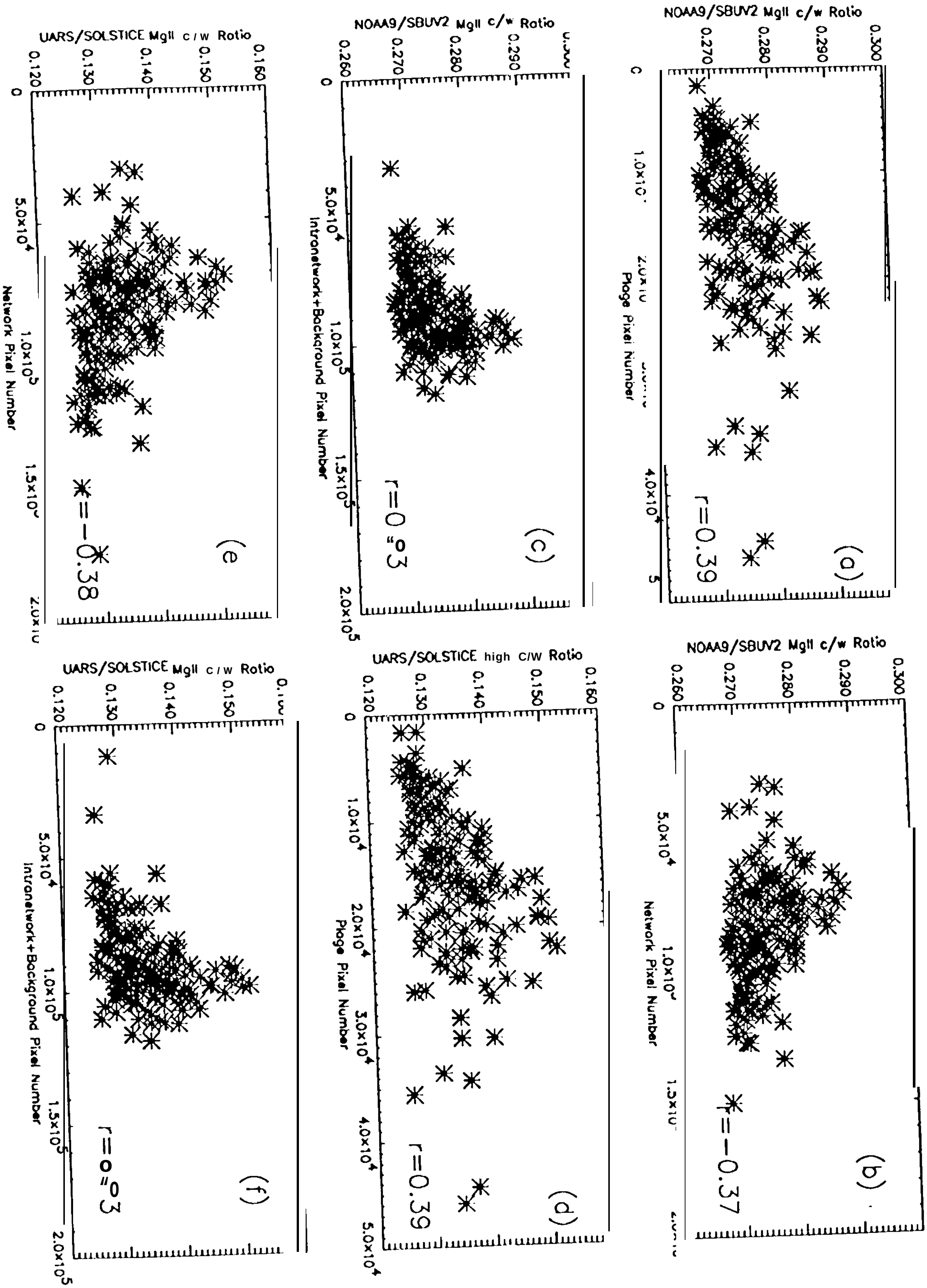

NOAA9/SBUV2 MgII c/w Ratio
Plage Pixel Number
r=0.39
(a)
NOAA9/SBUV2 MgII c/w Ratio
Network Pixel Number
r=−0.37
(b)
NOAA9/SBUV2 MgII c/w Ratio
Intranetwork+Background Pixel Number
(c)
UARS/SOLSTICE high c/w Ratio
Plage Pixel Number
r=0.39
(d)
UARS/SOLSTICE MgII c/w Ratio
Network Pixel Number
r=−0.38
(e)
UARS/SOLSTICE MgII c/w Ratio
Intranetwork+Background Pixel Number
(f)

Fig. 8